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PIGMENTS  
TO  
POWDERS, HANDLING



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but their large-scale production is complex and demands attention to every detail of the manufacturing process. This is because the application usefulness of inorganic pigments is determined by physical as well as chemical properties. Particle size, shape, and surface properties are as important in the pigment performance as chemical composition. For inorganic pigments that can exist in several crystal structures, controls must be exercised to make sure that the proper crystal habit having the optimum coloristic properties is produced.

Historical classification of inorganic pigments into the naturally occurring ones and synthetically produced ones is no longer useful. The majority of pigments is manufactured synthetically. For the purpose of this review, inorganic pigments are classified according to Figure 1.

### Properties

The value of pigments results from their physical-optical properties. These are primarily determined by the pigments' physical characteristics (crystal structure, particle size and distribution, particle shape, agglomeration, etc) and chemical properties (chemical composition, purity, stability, etc). The two most important physical-optical assets of pigments are the ability to color the environment in which they are dispersed and to make it opaque.

The opacity of a pigment lies in its ability to prevent a transmission of light through the medium. By doing so the pigmented medium obscures the subject on which it is applied. When light enters a pigmented medium and hits a pigment particle, the light can either be absorbed or dispersed by the particle. White pigments disperse the whole visible light spectrum more effectively than they absorb it; black pigments do the opposite. Color results when pigment particles absorb only certain portions of the visible light spectrum while dispersing the rest of it. Absorbed light changes into heat energy, which in the long run might have detrimental effects on the medium or pigment.

The opacity of pigments is a function of the pigment particle size and the difference between the pigment's refractive index and that of the media in which pigment particles are dispersed. The multiple light dispersion in the pigment-medium interface results in the appearance that the light is transmitted through a much thicker layer than it actually is. A pigment having a particle size between 0.16–0.28  $\mu\text{m}$  gives the maximum dispersion of the visible light. Any agglomeration of pigment particles can affect their opacity. Much effort has been spent to optimize particle size and size distribution and to prevent any particle agglomeration in order to achieve a maximum pigment opacity. The commercial value of pigments can also be enhanced by various surface treatments. The function of these treatments is to improve pigments' coloristic value or to simplify physical handling.

The most commonly measured pigment properties are elemental analysis, impurity content, crystal structure, particle size and shape, particle size distribution, density, and surface area. These parameters are measured so that pigments' producers can better control production, and set up meaningful physical and chemical pigments' specifications. Measurements of these properties are not specific only to pigments. The techniques applied are commonly used to

straightforward, the determination of peak intensities can be influenced by sample preparation. Any preferred orientation, or presence of several larger crystals in the sample, makes the interpretation of the intensity data difficult. The most common structures of inorganic pigments are rutile, anatase, and spinel.

**Physical and Chemical Properties.** *Particle Size.* Particle size and distribution are the most fundamental measured properties of powders (see SIZE MEASUREMENT OF PARTICLES). These properties impact a number of pigment characteristics. Those affected the most are the color (1,2), color strength, hiding power, and rheological properties. Particle size and distribution data can be easily misinterpreted. Only the data for spherical powders are easy to measure and interpret. Actual powders, however, consist of a population of particles of many different shapes. To complicate the matter further, powders are usually not formed from a mixture of single, free-flowing particles. The particles can be interconnected by weak forces, ie, electrostatic forces or liquid bridges, forming agglomerates; or by solid bridges, ie, chemical bonds or sintered necks, resulting in hard aggregates. To prevent powder dusting and make handling easier, some pigments are intentionally agglomerated to granules by the addition of granulating agents.

To permit a good description of powder population, a representative sample of the powder must be collected, measured, and the results interpreted using statistical methods. To simplify the mathematical evaluation it is usually assumed that particles are spherical and particle size is calculated as an average size. Particle size distribution (PSD) can either be presented in a graphical form as a distribution function, a histogram, or in a tabular form. For inorganic pigments to be useful in most applications, they must have an average particle size between 0.1 and 10  $\mu\text{m}$ . For these reasons only some of the particle size analysis (PSA) techniques have become widely accepted by the inorganic pigments industry.

Sieving analysis is one of the oldest and simplest methods in determining pigment particle size distribution. The analysis can be carried out using dry or wet samples. In some cases, only one sieve is used and the specification is set up as a maximum allowed retain of the sample on that particular sieve. Sieving can also be employed as the last operation in the pigment production to guarantee the absence of particles larger than the selected sieve aperture.

Sedimentation (qv) techniques, whether based on gravitational forces or centrifugation, derive the particle size from the measured travel rates of particles in a liquid. Before the particle analysis is carried out, the sample is usually dispersed in a medium to break down granules, agglomerates, and aggregates. The dispersion process might involve a simple stirring of the powder into a liquid, but the use of an ultrasonic dispersion is preferred (see ULTRASONICS).

Some particle size measuring techniques are more particle shape sensitive than others. Data obtained by different methods can be significantly different, and whenever a particle size is reported, the measuring technique and conditions should always be mentioned. Even using the same equipment, the extremes of the distributions (low and high 10%) are usually not readily reproducible.

A recent trend in particle analysis has been the introduction of personal computer-based automation (3). Sophisticated software packages can be used to automate and speed up the analysis. In some cases these computers can